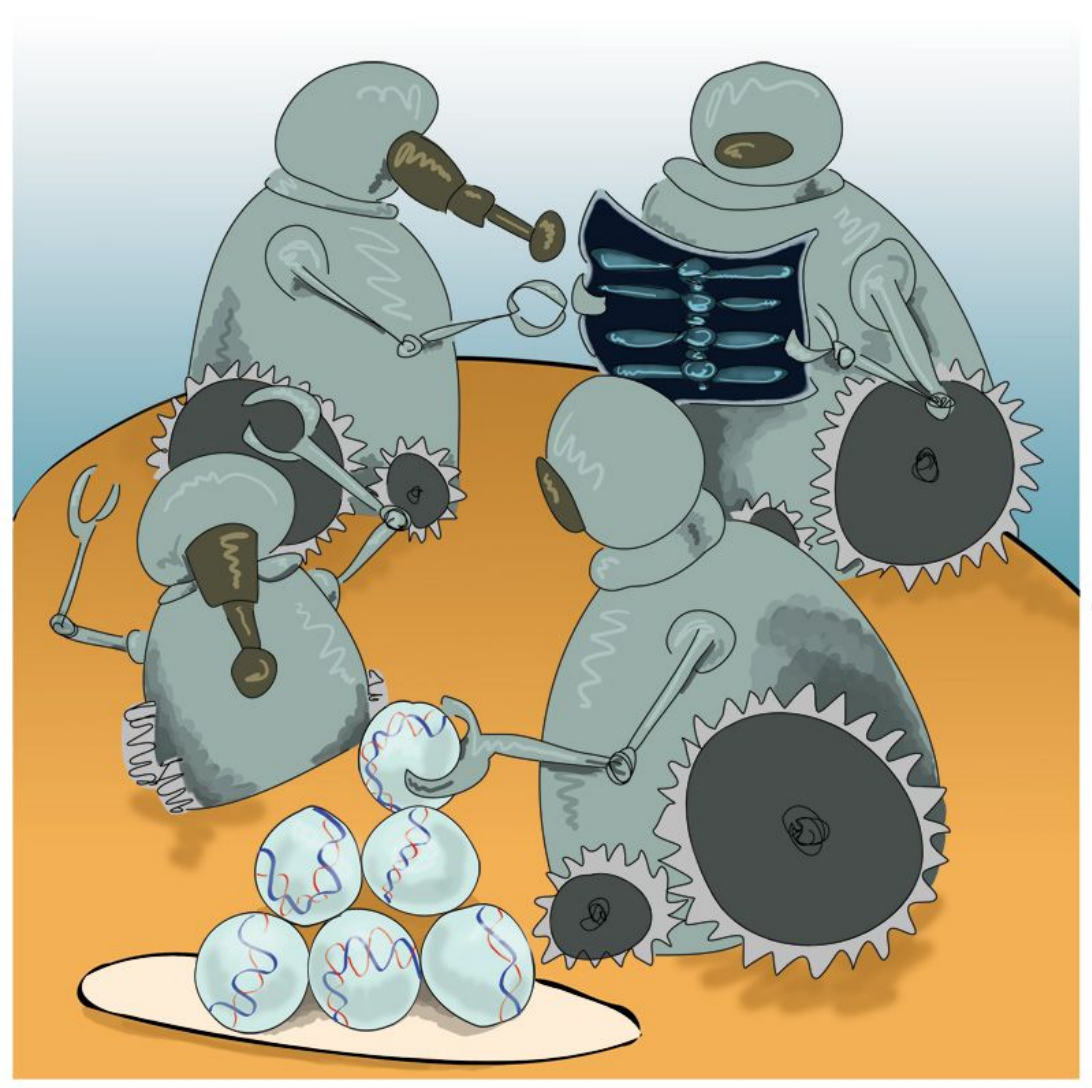
EGAN
European Genetic Alliances' Network



Innovative Medical Therapies:
Frequently asked questions

Foreword

In recent years, innovative therapies have advanced significantly, bringing new hopes and issues to the table. A decade ago they were only an abstract concept.

It can indeed be argued that all new therapies are innovative as, ideally, they offer a solution to a medical problem that was previously unavailable. However, this broad concept can be narrowed down, limiting innovative therapies to ones that involve new technologies, where scientific progress offers new possibilities of treatment for unmet medical needs.

Using this narrow concept still leaves many different areas of innovative treatments (see also last question). It is a rapidly evolving field, and trying to capture it in a booklet is like taking aim at a moving target. This FAQ thus highlights three select areas rather than providing a comprehensive overview. As their frequent presence in the media and in discussions can raise controversial issues, the areas we chose to look at are stem cell therapy, gene therapy and nanotechnology.

We hope this booklet gives a balanced view of Innovative Medical Therapies as it is now and for the immediately foreseeable future. It is the result of a collaboration between the patient group EGAN (European Genetic Alliances' Network) and Roche, with EGAN collecting commonly asked questions and Roche experts formulating answers that have been checked by independent specialists.

We welcome comments and feedback. Please send these to me at alastair@geneticalliance.org.uk.

Alastair Kent
President EGAN
alastair@geneticalliance.co.uk

Contents

Introduction

What are innovative medical therapies?

Innovative medical therapies are a fluid concept that encompasses many evolving fields of medical science. What they share is a goal: They all aim to repair, replace, restore or regenerate cells, tissues and organs that are damaged or diseased. Branches of innovative medical therapies look into regrowing liver cells, into replacing skin lost in a fire or into repairing single cancerous cells.

This leaflet looks at three areas of innovative medical therapies: stem cell therapy, gene therapy and nanotechnology.

What hurdles generally delay patient access to innovative treatments?

While each innovative treatment comes with a specific set of questions, there are some challenges that many innovative treatments face, albeit to varying degrees:

- Research costs:
  Research, especially basic research into new areas, is expensive, leading to a potential reluctance to explore new ideas.
- Research hurdles:
  Some innovative treatments involve areas of research where regulation might be very strict.
- Lack of clinical experience:
  Experiences with innovative treatments are naturally limited, so unforeseen effects are perhaps more likely and it might take additional time to reduce risks and optimise the treatment.
- Scepticism and lack of knowledge of medical experts:
  Innovations with a complex scientific background are time-consuming to understand. Faced with news of medical inventions on a daily basis, not all medical experts have the skills and knowledge to distinguish between a promising innovation and one that is oversold.
- Ethical issues:
  Some innovations raise ethical questions that are hard to answer, leading to scepticism or even disapproval within the media and the public.
- Health Literacy:
  While the patient community increasingly wishes to be involved in the process at an early stage, lack of understanding regarding new, innovative and often complex treatments is common.

Stem Cell Therapy

What are stem cells?

Stem cells could be compared to marbles rolling down a hill: there are a hundred ways they could roll down, but once they are rolling one way, they cannot go back. In slightly more accurate terms: Stem cells are undifferentiated cells with the ability to produce numerous, identical copies of themselves which can then develop into various types of cells (e.g. liver cells, heart cells, blood cells). This characteristic makes them particularly valuable for medicinal use.

Three types of stem cells have been identified:

- ***Adult stem cells*** (sometimes also referred to as *somatic stem* cells) are derived from tissues like bone marrow or cord blood and give rise only to specific cell types, e.g. cells of the tissue in which they are found. Their importance lies in their ability to replace cells that were lost due to an injury and thus serve as an internal repairing mechanism.
  It is challenging to isolate adult stem cells in sufficient numbers, and science has not yet managed to expand their numbers significantly in cell culture; hence additional research on embryonic and induced pluripotent stem cells is needed.

- ***Embryonic stem cells***, as their name suggests, are found in embryos. Embryonic stem cells are pluripotent, meaning that they can develop into any fetal or adult cell type (blood, heart, brain cells, etc.), but they can't develop into a complete organism.

- ***Induced pluripotent stem cells*** (often abbreviated as *iPS*) are derived from adult body cells (for example skin cells). Biochemistry makes it possible to reverse them to an early, pluripotent stage,[1] so that they exhibit similar properties as embryonic stem cells. If iPS cell technology develops in line with early expectations, it may eventually replace the need to derive stem cells from embryos.

What is stem cell therapy and how does it work?

Stem cell therapy describes a medical procedure in which stem cells are injected into a person's body (or into an organism) so as to repair tissue or grow organs.

There are a number of characteristics that stem cells must reliably possess in order to be useful for therapeutic purposes:

- They must reproduce themselves in sufficient quantities.
- They have to differentiate into the required type of cell.
- It must be ensured that they don't harm the recipient, e.g. it must be ensured that the cells don't form cancerous tissue and the donor needs to be tested for various diseases (as it is done for blood transfusions).
- Typically, they need to survive in the recipient's body and integrate into the surrounding tissue.

[1] In 2006, Japanese researchers were the first to successfully reprogram the cells of mice; in 2008, a Harvard scientist succeeded in reversing human skin cells first to stem cells, then to nerve cells.

For what sort of diseases might stem cell therapy represent a useful treatment?

There are many medical conditions where stem cell therapy might help as a cure in the future; conditions such as Alzheimer's, diabetes, Parkinson's or heart attacks have in common that tissue is destroyed or damaged, leading to organs no longer functioning properly. The lost or defunctive cells can potentially be replaced by stem cells.

To give one example, the immune system of patients with type 1 diabetes destroys their own insulin-producing cells in the pancreas. By triggering cultured stem cells to differentiate into insulin-producing cells, it might become possible to replace the lost cells in the patient's body. Another example would be autologus studies (meaning that the donor and the recipient of a blood transfusion or transplantation are the same person) are ongoing in Crohn's disease as of year 2011.

Naturally, attention focuses on diseases where no treatment (or only symptomatic treatment) is available so far. At the same time, scientists hope that research into cell division mechanisms will foster our understanding of complex diseases such as cancer, to the point where existing treatments can be improved or new treatments can be developed based on our growing knowledge.

There are two additional medical uses of stem cells. Firstly, they might bring improvements in the area of drug delivery due to a specific ability called "homing;" it is an ability displayed e.g. by Pacific salmons or migratory birds and means they can find their destination even through unfamiliar territory. In areas where targeting of drugs is difficult yet highly advantageous, this ability could make stem cells valuable vehicles for drug delivery. Highly invasive and infiltrative tumors, for instance, could be treated much more effectively and with fewer side effects. A second additional use is seen in the area of clinical trials, where human tissue grown from stem cells could help in the evaluation of new treatments.

Is this still research or do physicians already treat patients with stem cell therapy?

The current use of stem cell therapy is mostly experimental, with news of research results and experimental studies a daily occurrence in the research community.

An exception is one well-established stem cell treatment in the area of cancers, notably leukemia and lymphoma, which counteracts the negative effects of chemotherapy. As chemotherapy affects most growing cells, it also affects blood stem cells within the bone marrow (a spongy tissue inside bones). These cells differentiate into all types of mature blood cells. By introducing a donor's healthy blood stem cells into the patient's bone marrow, stem cell therapy replaces the cells lost during chemotherapy.

Will stem cell therapy provide a permanent cure or will it take repeated treatments to control a disease?

It will take many preclinical and clinical studies to find a definite answer to this question.

Generally, the answer will vary and depend, among other factors, on the indication and complexity of the disease; another aspect is whether the recipient's immune system rejects the donated cells.

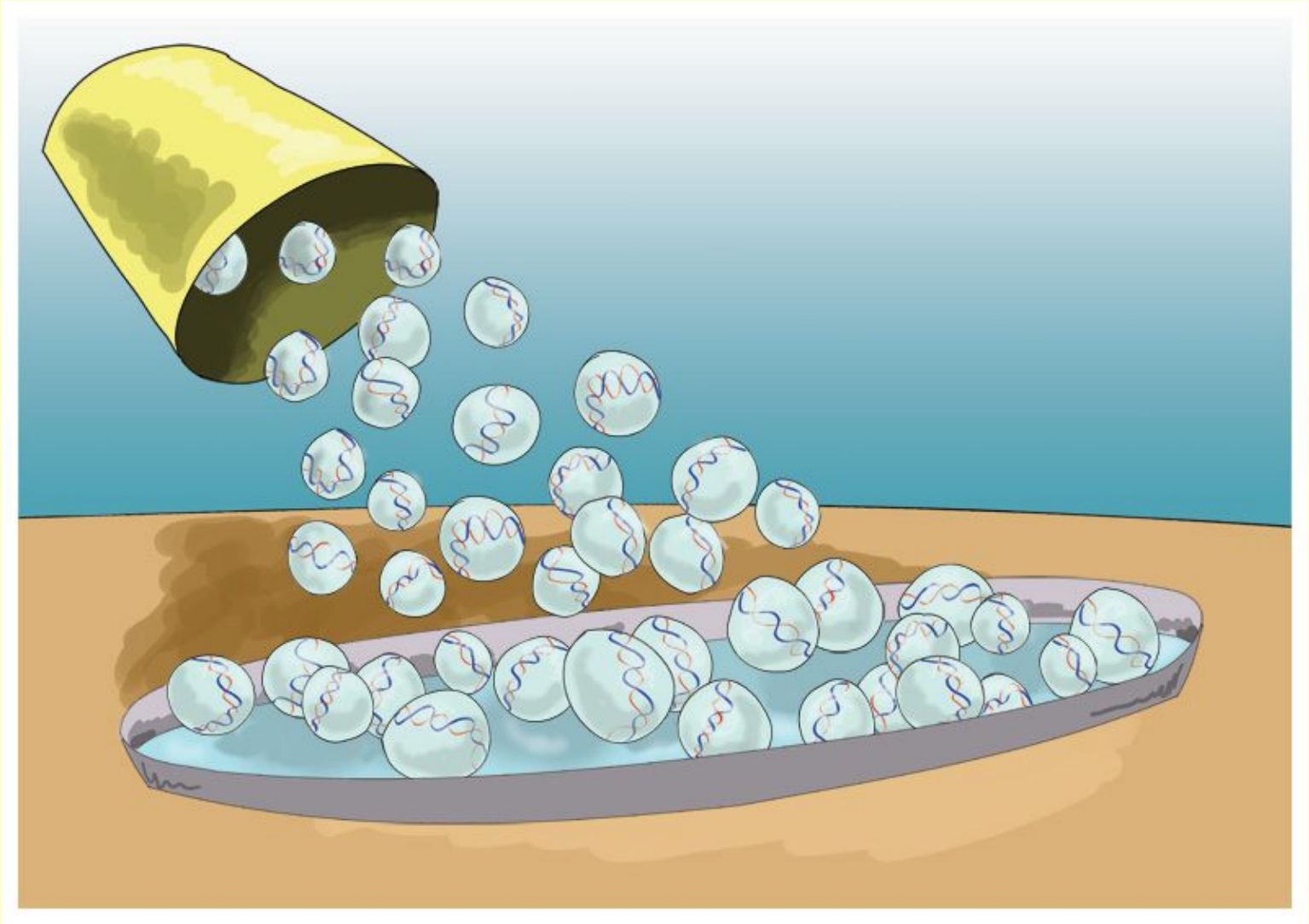
Using stem cells to replace lost tissue, for instance, ideally means that the donated cells will integrate into the patient's body and replace the lost tissue without a need for repeated treatments. A stem cell treatment for diabetes, on the other hand, would be far more complicated: Taking the example of diabetes type 1, it is caused by the patient's immune system turning against itself and destroying insulin-producing beta cells of the pancreas. Simply replacing the diseased cells could thus provide only temporary relief, as the patient's immune system would destroy the new cells as well. The treatment would have to be repeated at regular intervals.

In conclusion, researchers are looking for permanent cures, but they may not always be within reach.

How does medical research profit from stem cells?

Stem cell research is expected to improve our knowledge about characteristics of human cells. Scientists are aware that many diseases and malfunctions (e.g. cancer) result from abnormal cell division and differentiation, so research into the basic characteristics of stem cell behavior might yield valuable insights and eventually enable scientists to control those mechanisms.

Another area where stem cells might prove useful could be the testing of drugs. Research could sort through a broader range of substances in a shortened amount of time and thus make the drug research process more effective. Additionally, pluripotent stem cells could help researchers to evaluate the safety of a new treatment. Employing stem cells in this area might both shorten the time needed to test a new compound as well as enhance the safety of persons enrolled in clinical trials.



Are there any risks specifically associated with stem cell research and therapy?

Stem cells offer many treatment possibilities which might aid research and enhance the safety of clinical trials. Additionally, their study might improve our understanding of cell division and differentiation processes, which play a role in many severe diseases. Stem cell therapy might thus alleviate or even cure various diseases.

However, its considerable potential must be contrasted with a number of concerns; it must be ensured that stem cells help rather than harm the patient. For instance, studies with regenerative stem cell therapy indicated a heightened risk of developing tumours in mice. While it is unclear whether the same effect would be observed in humans, the risk must be dealt with adequately. Therefore, an important safety-related question is whether stem cells act and differentiate as planned, or whether they might differentiate into undesired cell types such as cancer cells. A lot of long-term studies currently focus on excluding this severe side effect. Other studies address problems such as stem cells moving to the wrong place in the body or the rejection of transplanted cells by the host's immune system.

In summary, there are several concerns related to stem cells, and further preclinical and clinical studies are required to address them adequately. Only then can we fully benefit from the potential that stem cells offer.

Are there ethical concerns specifically associated with stem cell research and therapy?

The ultimate purpose of stem cell research – to alleviate human suffering – is largely undisputed. However, ethical debate has sprung up around the means. While research and therapy with adult stem cells are largely accepted, a lively discussion surrounds the use of human embryonic stem cells for research purposes. Most of those cells come from embryos that are typically four or five days old, developing from eggs that have been donated to research and weren't fertilized in a woman's body, but in a *in vitro* fertilizing clinic. (Fetal tissue is another source of embryonic stem cells.)

Some people question whether it is ever acceptable to use donated embryos for research. Does the end justify this means? Does it make a difference how the egg it develops from has been fertilized? What rights does an embryo have at which stage of its development?

In simple terms, the most important question is whether a developing embryo of four or five days is seen as a human being or not. The legal answer to this question differs from country to country. The moral answer, on the other hand, doesn't obey country borders and differs depending on a person's beliefs and value system.

So as to avoid the complex issues tied to embryonic stem cells, research increasingly focuses on induced pluripotent stem cells (iPS), derived from adult cells). Science is still working out the detailed characteristics of iPS, but they hold great potential while avoiding the ethical conflict associated with embryonic stem cells.

The patient view on stem cell therapy

Recent research suggests that stem cells have great possibilities for creating therapies for many intractable conditions. Scientists see them as possible treatments for neurological diseases such as strokes, Parkinson's and Alzheimer's, for immunological conditions and also for a range of other conditions. While this is very exciting for patients, it would not be wise to succumb to the hype that surrounds these novel therapies.

Realizing the potential of stem cell therapy will require a sustained effort. Stem cell based treatments will emerge in time, but results do not happen overnight. I am sure that given time, we will see the development of safe and effective stem cell therapies – but only if we can only sustain the investment in research and development that will be required to achieve this.

Gene Therapy

What is gene therapy?

A gene is a segment of the human chromosome and consists of DNA. By controlling heredity and determining the specific function of cells, a person's genes provide their basic biological code. To paint a simple picture: If a person's DNA is the detailed construction plan of a house, chromosomes are the rooms and genes the bricks that form the rooms' walls. Each person's DNA has 46 chromosomes (23 pairs) and approximately 25'000 genes.

In the case of genetic diseases, part of a gene – and thus part of the code – is malfunctioning. This is where gene therapy comes into play. Genes are introduced into the patient's body to cure a disease or restore a missing function. Gene therapy aims to repair or replace the malfunctioning gene.

How does gene therapy work?

The story of the Trojan horse might help to explain the basic idea of gene therapy: The legendary Greek soldiers built a giant horse statue in which a small group of soldiers hid. Once the statue had been pulled into the city of Troy, the soldiers climbed out and opened the city's gates to their comrades.

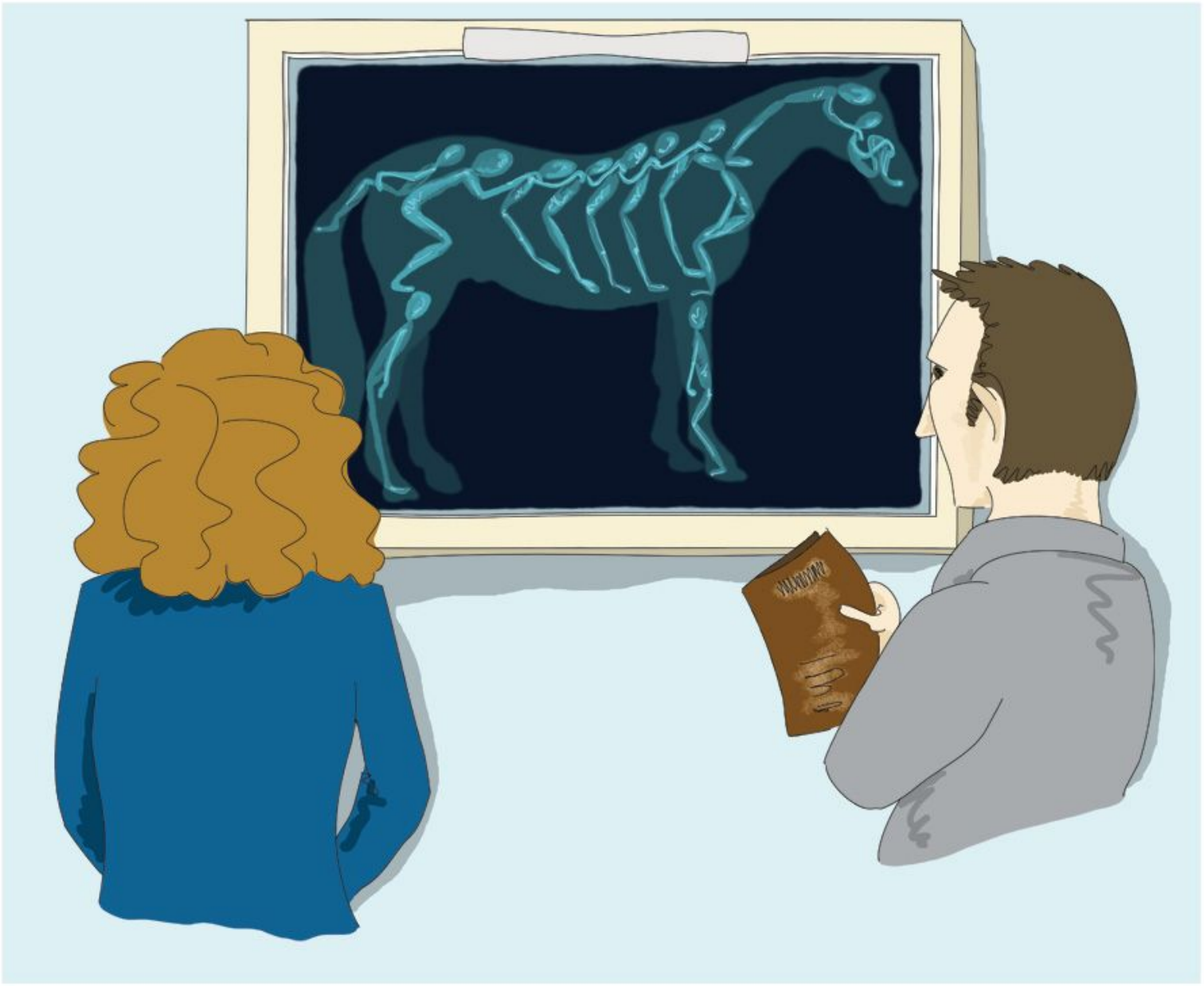
Similarly, gene therapy uses a vehicle that can get past a cell's defence mechanism: Viruses have the inherent ability to penetrate host cells and alter the host cell's DNA, prompting it to produce the DNA of the virus instead. This makes viruses the perfect Trojan horses for gene therapy.

First, they are genetically altered to carry segments of normal human DNA, which they then smuggle into the cell.

Once it passed the cell's walls, the virus injects its passenger – the healthy gene – into the cell. The cell's DNA is then recoded to replace or repair the malfunctioning gene, meaning that the cell is now able to function normally.

While viruses are the most common vehicles of gene therapy, there are other options:

- **Direct injection** of functioning DNA into the cell: This is the simplest method, but its use is limited to certain tissues and requires large amounts of DNA.
- **Liposome**: Instead of a virus, the vehicle can be an artificial lipid sphere with a core made of water. This liposome is also able to pass through the cell's barriers.
- **Binding molecules**: Molecules that bind to specific cell receptors can carry therapeutic DNA, which is then engulfed by the cell.
- **Chromosome 47**: Researchers are experimenting with an additional – artificial – chromosome that would exist autonomously beside the other 46 chromosomes and could carry substantial quantities of genetic code. However, a molecule that large might prove more difficult to inject into the target cell.



Are there different types of gene therapy?

It can be useful to distinguish between somatic gene therapy and germ-line gene therapy:

- **Somatic gene therapy** transfers DNA to the tissue of a specific individual, which means that the therapeutic results are limited to that specific individual and can't be passed on to the offspring. Research currently focuses on this method.
- **Germ-line gene therapy**, on the other hand, transfers DNA to reproductive cells (meaning cells that produce eggs or sperm). The effect is therefore passed on to future generations. Due to technical, legal, ethical and safety concerns, germ-line therapy is currently a theoretical concept rather than a concrete area of research.

Another distinction is made between different purposes of the therapy:

- **Gene augmentation therapy**: Rather than actually substituting the defective or missing gene, gene augmentation therapy adds a functional copy of the gene to the cell's DNA. The aim is to have the healthy copy produce the necessary functional product – on the side, so to speak. This approach could be particularly useful for genetic disorders that are marked by the loss of a functional gene product.

- **Gene inhibition therapy**: In this case, the inserted gene interferes directly with the functioning of a defective gene (or with the activity of its product). Simply put, the inserted gene aims to keep the malfunctioning gene from expressing itself. This approach might treat infectious diseases, cancer and genetic disorders that are caused by inappropriate gene activity.
- **Killing of specific cells**: In some cases, a certain cell population is the cause of a disease – for instance, mutated cells are the cause of cancer. It might be possible to erase the population of mutated cells by inserting a "suicide gene" into this specific cell population, e.g. a gene which creates a toxic product. For obvious reasons, this suicide gene would have to target a very specific cell population, or it would lead to the widespread death of body cells.

As for where the injection of therapeutic DNA happens, there are basically two methods:

- The ***in vivo*** method means that altered DNA is injected directly into the patient.
- ***Ex vivo*** means that cells are extracted from the patient, genetically altered in the lab, and then eturned into the patient's body.

What sort of diseases might gene therapy be useful on a treatment for?

Gene therapy holds potential for a number of different conditions. It was initially conceived as an approach for treating **inherited monogenic or "single gene" disorders** such as childhood blindness or cystic fibrosis, but the scope of prospective gene therapies has now grown to include treatments for **multifactorial or common complex diseases,** meaning conditions that result from both multiple genes as well as from environmental factors, e.g. disorders such as arthritis, diabetes or cancer.

Two concrete examples of disorders that might be a target for gene therapy:

Childhood blindness / Leber's Congenital Amaurosis (LCA):

LCA describes a group of rare inherited eye diseases that result in retinal dysfunction and, subsequently, in vision loss. A group of scientists managed to insert healthy copies of the malfunctioning gene into the cells of the retina so as to prompt normal functioning. While no effective treatments are currently available, research in this field is fairly advanced and could have a significant impact on future treatments for childhood blindness.

Cystic Fibrosis (CF):

Cystic Fibrosis (CF) is the most common life-threatening single-gene disease among Caucasians. It is a chronically debilitating condition, caused by a single malfunctioning gene which encodes a protein (CFTR) to regulate the components sweat, digestive juices and mucus. Due to the malfunctioning gene, patients produce thick, sticky mucus that clogs the lungs and the pancreas and leads to life-threatening infections and shortness of breath.

Existing treatments are currently only supportive: physical rehabilitation, maintenance of nutritional status or improvement of respiratory function to the point of lung transplantation.

Gene therapy in Cystic Fibrosis aims to deliver normally functioning DNA into the affected cells. It holds the promise of life-saving treatments for CF patients since it targets the causes rather than treating only symptoms, but treatment has yet to be developed to a clinically useful stage. Currently, researchers are trying to optimize various steps to maintain a therapeutic benefit.

Complex diseases - such as Parkinson's disease, cancer or cardio-vascular conditions - typically occur when environmental factors cause genes to malfunction, or when environmental factors and one or more already malfunctioning genes combine. While these diseases may have a genetic aspect, they are not necessarily inherited. **Cancer**, affecting many different cells in the body, will be difficult to cure with gene therapy, but gene therapy may turn out to have therapeutic results when used in combination with other treatments.

As a rule of thumb: the less complicated the disease, the higher the potential for gene therapy. It is expected to have the biggest impact on the treatment of diseases that require only a small number of genes and cells to be fixed.

Is this still research or is gene therapy already being used to treat patients?

While some clinical trials have taken place, gene therapy is still largely a concept of the future. Most treatments are at an experimental stage.

An example for an experimental treatment:

In 2009, German physicians published a report in the *New England Journal of Medicine.* It detailed the story of a patient who appears to have been cured of HIV.

The patient, suffering from leukemia in addition to HIV, was in need of a bone marrow transplant. A search for donors returned an unusually high number of matches. It gave his physicians an idea: What if the stem cell transplant, in addition to counteracting the negative effects of chemotherapy, came from a donor with a naturally occurring genetic resistance to the human immunodeficiency virus?[2] Could a transplant like that also prompt the patient's body to develop a genetic resistance to the virus already affecting it?

The tentative answer is yes. After six-hundred days without the standard antiretroviral drug treatment, the patient showed no signs of either disease since the stem cell transplant.[3]

Given the complexity of the matter, scientists see many hurdles ahead of them, for instance:

- The vectors, be it a virus or something else, must be safe. It must be ensured that they are harmless to the patient's body, meaning they don't cause other diseases, lead to allergic reactions or interfere with the normal workings of other genes.
- Repairing enough cells to make a difference is difficult; it still poses a challenge to have the cells incorporate the therapeutic DNA segment so that each cell division reproduces the functioning DNA. Scientists must therefore find a way to repair entire populations of target cells (or at least a sufficiently large proportion of a cell population for therapy to be effective).
- The cells carrying the functional, repaired DNA must be stable and long-living. An ideal scenario would allow scientists to repair not so much the specialised cells themselves, but rather the cells producing them; if it were possible to identify and repair the right stem cell population, they would start to produce healthy cells instead defective ones. With time, those repaired stem cells would then replace all defective cells with functioning ones. (For more on stem cells, see the relevant section in this leaflet.)

[2] The resistance results from a specific mutation that prevents a molecule called CCR5 from appearing on the surface of cells. As nearly all strains of HIV use CCR5 to enter a host cell, its absence means that the virus can't find entry.

[3] Hütter G, Nowak D, et al. Long-term control of HIV by CCR5 Delta32/Delta32 stem-cell transplantation. N Engl J Med 2009;360(7):692-8.

Due to these hurdles, gene therapy is not something that is likely to be a common treatment within the next few years. It will take time and careful research, especially given the potential risk inherent in manipulating the human body at such a basic level.

Will gene therapy provide a cure or will patients need repeated treatments to control their disease?

The ultimate goal of gene therapy is to provide a cure by repairing stem cells, prompting them to produce new, differentiated cells that are healthy. Unfortunately, that goal is not yet within reach.

Most of the more advanced projects for gene therapy focus on repairing a population of specialised cells, which can only divide a limited number of times before they die. At the same time, stem cells – which have not been repaired – continue to produce specialised cells that carry the defective gene. Over a certain span of time, the proportion of healthy, repaired cells will thus decrease, replaced by an increasing number of newly produced, defective cells. Until scientists manage to repair the stem cells rather than their product – in other words, until scientists succeed in changing the mould rather than its imprint – repeated treatment is necessary.

Are there any risks specifically associated with gene therapy?

Before gene therapy can truly advance and become an established method of treatment, a number of safety concerns must be addressed:

- Some scientists are concerned that the therapeutic genes themselves may cause disease.
- There is a certain risk that the viruses that have been altered to act as vehicles combine with other viruses to form a disease-causing strain.
- Another risk associated with gene therapy is that the altered viruses may cause allergic reactions with potentially severe consequences.
- The newly introduced genes have to seamlessly integrate into the person's system, without interfering with the workings of healthy genes.

Are there specific ethical concerns associated with gene therapy?

As gene therapy interferes with the basic setup of humans, it is not surprising that it triggers ethical discussions, many of them focusing on germ-line therapy (gene therapy that introduces DNA to reproductive cells). The following list of ethical questions is incomplete, but it should convey an idea about the complexity of the matter:

- Are there lines that science should never be allowed to cross, and if so, does the interference with a person's DNA constitute one of these absolute taboos?
- What constitutes a condition that should be rectified by gene therapy? Where is the line between what is normal and what is a disability or disorder?
- As gene therapy may interfere at a basic level, before birth, could it enhance positive traits such as intelligence, attractiveness or physical fitness of a person? Should the enhancement of such traits be allowed? Will this lead to "designer children" who possess traits that have been chosen by their parents?
- Will the – probably high – costs of gene therapy make it a therapy only available to the rich?

The patient view on gene therapy:

Patients and patient organisations are amongst the keenest advocates for research and development in gene therapy. Their benefit is not in getting a scientific degree or title, earning money or even being on the news; their benefit is in improving health and overcoming a life-threatening disease, in cure rather than care (though some groups may provide care as part of their support for patients and families). Gene therapy has the potential to make a gene medicine possible, and that potential is the drive for patients to promote and support gene therapy.

As usual when it comes down to the application of new insights and therapies, ethical issues start playing an important role – this is particularly true for gene therapy, which influences the basis of life: the DNA. Ethics are important when, for example, working out the necessary safety protocols, clinical trial setups and inclusion criteria of patients for research and treatment.

The development process of effective cures hinges on trust, a trust which can only come from mutual respect, transparency and commitment to collaboration. If these conditions are fulfilled, gene therapy offers significant promises for patients with inherited genetic diseases.

Nanotechnology

What is nanotechnology?

Nanotechnology is the science of small things. Very small things. Very, very small things. While definitions vary, at its most basic, nanotechnology can be described as the manipulation of materials on a scale of 1-100 nanometres, a scale that is about 80 000 times smaller than the diameter of a human hair. The small size leads to quantum effects and vastly increases the ratio of surface area compared to volume, which is why particles tend to attain novel characteristics that are not observed on a larger scale. These novel characteristics are at the centre of nanotechnology.

Rather than being seen as a branch of any specific scientific or technological discipline, nanotechnology is cross-disciplinary, encompassing and combining relevant areas of chemical, physical, biological and information technologies. The new characteristics shown by matter at a nanoscale level have led to nanotechnology being viewed as one of the key technologies of the 21st century.

While current applications of nanotechnology are limited to only a few areas (e.g. as a pigment in lipstick, in the coating of self-cleaning windows or in diagnostic procedures), future applications are expected for a wide range of areas. For instance, it promises advances in the quest for even more powerful computers and other electronic devices, it might aid in purifying, detoxifying and desalinating water or lead to ultra-strong materials and protective suits that are activated by the detection of a biological agent. Nanomaterials may be useful in architecture, manufacturing, textile and other high-tech industries.

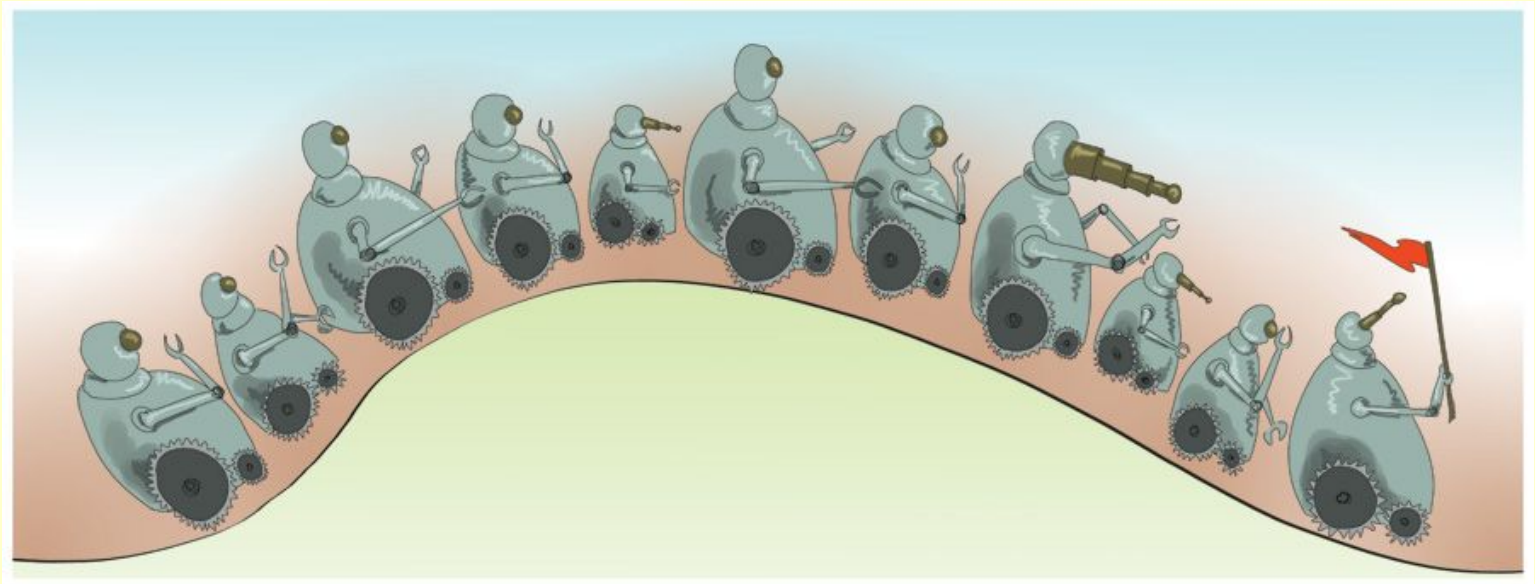
For what sort of diseases might nanotechnology help to produce useful treatments?

Nanomedicine promises solutions and improvements in practically every branch of medicine, in diagnosis as well as in treatment:

- **Nanobots** are miniaturized robots programmed to perform routine surgical procedures. One day, they might make surgery at the cellular level possible - for example, removing individual diseased cells or even repairing defective portions of individual cells.
- Nanomedicine has also become an important tool in **molecular imaging**, using nanoparticulate formulations of various chemical compounds such as, for example, iron oxide or gold. They allow for a more detailed detection of various disease symptoms, leading to improvements in the treatment of cardiovascular diseases such as thrombosis or myocardial infarction (commonly known as heart attacks).
- In **nanoneurology**, nanowires are being developed for monitoring brain activity.
- Targeted drug delivery by nanoparticles is a promising field that has advanced rapidly in the treatment of cancer, also known as **nanooncology**. Already, nanoparticles are able to deliver chemotherapy drugs directly to tumor cells and then give off a signal after the cells are destroyed. Particularly well known is liposomal drug delivery, the delivery of a drug in a tiny vehicle. For instance, liposomal formulations of a specific chemotherapy agent are approved for the treatment of breast cancer and are much more effective compared to standard treatment, with patients showing fewer side effects than they show with standard formulations.
- Nanotechnology also plays a role in the treatment of **infections**, promising the elimination of bacterial infections in a patient within minutes, instead of using treatment with antibiotics over a period of weeks.
- Nanomaterials of various compositions are being developed in the area of **regenerative medicine**.
- Nano-sized molecules can be made to take on many shapes and functions and could therefore act as antibodies or enzymes.

Many of the new technologies are applied in challenging areas, where either no satisfactory treatments are available or experiments suggest that nanotechnology-based methods are more effective than the conventional approaches. Rapid advances in the application of nanotechnology have been made in the area of cancer, both in diagnostics and in therapeutics. For instance, an increasing amount of attention is devoted to behavioural differences in, theoretically, identical cancer types from one patient to another. Personalization of cancer therapies is based on a better understanding of the disease at the molecular level and nanobiotechnology is likely to play a role in this area.

Nanotechnology is expected to play a role in increasing the personalization of medicine, such as the identification of so-called biomarkers, which are individual characteristics that make two patients with the same diagnosis react in different ways to the same treatment (see also the FAQ on Personalized Healthcare, linked at the end of this brochure).



Is this still research or do physicians already treat patients using nanotechnology?

A number of nanotherapeutic formulations have been approved and are particularly well established in the area of cancer.[4] However, most of nanomedicine's potential has yet to move past the stage of research and experimental trials. Nanobots, patrolling the body for disease and repairing malfunctioning cells, are a dream of the future that won't become our present for a while yet. Until then, nanomedicine is expected to evolve gradually while our knowledge grows along with the range of available applications.

Are there any risks specifically associated with nanotechnology?

In shifting its focus to the nanoscale and the practice of nanomedicine, medical practice enters a new era. The potential impact of nanomedicine on society is huge and the nanopharma market is expected to grow significantly over the coming years.

While there are no risks specifically related to the use of nanoparticles in medical devices that perform diagnosis in a lab setting, concern has been expressed about the therapeutic introduction of nanoparticles into the human body. It is possible that changing the particle size of substances might alter their characteristics significantly and in ways that are hard to predict. What's more, the increasing use of nanotechnology means that more and more man-made nanoparticles will enter the environment and, due to their new characteristics, could affect nature or human health. For this reason, nanotoxicology has emerged as an integral part of all nanotechnology research fields. Nanomedicine products will have to undergo extensive preclinical and clinical testing to exclude harmful effects before entering clinical application

[4] Zhang, L. et al. Nanoparticles in medicine: therapeutic applications and developments. Clin. Pharmacol. Ther. 83, 761–769 (2008): http://dx.doi.org/10.1038/sj.clpt.6100400

Will nanotechnology provide a cure or will patients need repeated treatments to control their disease?

Nanotechnology might bring new solutions to various medical areas, including diagnostics and treatment. Due to the enormous range of different applications, nanomedicine may be able to cure some conditions whereas in other areas, its use will likely be limited to making medical treatments more accurate and effective. In some cases, improved effectiveness of a treatment might significantly improve the chances of a full recovery.

The patient view on nanotechnology:

Patients have an interest in innovative methods for delivering effective diagnostics and/or therapeutics. Nanotechnology is one such development that could result not only in novel ways of delivering pre-existing products, but also in the creation of totally new therapeutic entities.

Of course patients want their treatments to be safe and effective, but in practice their primary concern is whether the treatment works - or not - rather than the nature of the technology required to deliver it. Patients taking part in a recent project funded by the European Commission[5] concluded that nanotechnological developments could be accommodated within existing regulatory procedures and that there was no immediate need to increase the regulatory burden unless evidence emerged to the contrary.

Conclusion

Are there any other possible treatments that might be called "Innovative Medicines"?

There are various other treatment methods that might be called "innovative medicines." Personalised Healthcare, for instance, is an approach that differentiates between patients based on individual characteristics such as a mutation in a specific gene or the body's ability to process a drug. Those characteristics then guide treatment decision such as the choice of medication or the dose or duration of the treatment (see also link to Personalised Healthcare FAQ at the end of this brochure).

Another innovative approach is the use of genetically modified viruses in cancer therapy. Often referred to as oncolytic viruses, these altered viruses could be a new weapon in the arsenal of oncologists. Oncolytic viruses invade tumour cells and multiply inside of them, eventually killing their hosts without infecting or harming healthy cells. A small trial with modified herpes viruses recently showed promising results in the treatment of head and neck cancer; it will now be expanded to include a higher number of patients for a Phase III trial.[6]

However, Personalised Healthcare and oncolytic viruses are just two examples of science's recent advances. As our understanding of the human body's complexity grows, the range of possibilities widens, and so does the range of innovative treatment options.

[5] Nanomed Round Table: http://www.nanomedroundtable.org/

[6] Harrington K, Hingorani M, et al. Phase VII Study of Oncolytic HSVGM-CSF in Combination with Radiotherapy and Cisplatin in Untreated Stage IIVIV Squamous Cell Cancer of the Head and Neck. Clinical Cancer Research 2010; 16(15): 4005-15.

Further reading

World Medical Association – Statement on Embryonic Stem Cell Research:
http://www.wma.net/en/30publications/10policies/s1/index.html

World Medical Association – Statement on Genetics and Medicine:
http://www.wma.net/en/30publications/10policies/g11/index.html

World Medical Association – Statement on Genetic Counseling and Genetic Engineering:
http://www.wma.net/en/30publications/10policies/c15/index.html

Gene Therapy and Ethics: The Patient View - A tool for patients dialogue & . EGAN. Available on:
www.biomedinvo4all.com/en/publications

Gene Therapy and Ethics: The Patient View - A tool for public dialogue. EGAN Available on:
www.biomedinvo4all.com/en/publications

A patient and family perspective on gene therapy for rare diseases. Alastair Kent and Cor Oosterwijk in: J Gene Med 2007; 9: 922–923.

Other FAQs in this series:

All new FAQs will become available on www.biomedinvo4all.com; they are often available in various languages (e.g. German, French, Greek, Dutch, Bulgarian).

Social and Psychological Aspects of Medical Testing:
http://www.biomedinvo4all.com/en/publications/faq-on-social-and-psychological-aspects-of-medical-testing/

Clinical Trials:
http://www.biomedinvo4all.com/en/publications/faq-on-clinical-trials-various-languages/

Personalised Healthcare :
http://www.biomedinvo4all.com/en/publications/faq-on-personalised-healthcare-various-languages/

Biobanks:
http://www.biomedinvo4all.com/en/publications/faq-on-biobanks-various-languages/

illustrations by www.rebeccajkent.com